

**SLOT MOTOR INCLUDING LEGS ENGAGING OPENINGS OF CIRCUIT
BREAKER HOUSING AND ELECTRICAL SWITCHING APPARATUS
EMPLOYING THE SAME**

5 BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to electrical switching apparatus, such as, for example, circuit breakers and, more particularly, to circuit breakers employing a slot motor.

10 Background Information

Circuit breakers, such as molded case circuit breakers, include at least one pair of separable contacts. A first contact is fixed within the molded case housing and a second movable contact is coupled to an operating mechanism. These separable contacts are in electrical communication with either the line or the load coupled to the circuit breaker. The operating mechanism moves the movable contact between a first, open position wherein the movable contact is spaced from the fixed contact, and a second, closed position wherein the fixed and movable contacts are in contact and electrical communication. The operating mechanism may be operated manually or by a trip mechanism.

20 The exterior walls of molded case circuit breakers have typically been
a weak link for case strength and a limiting factor in increasing the interrupting
ratings of circuit breakers.

In order to enhance the speed of separation of the separable contacts, the contacts may be disposed within a slot motor, which increases interruption performance. The slot motor is a ring or loop-shaped device made of magnetically permeable material (*e.g.*, steel), which surrounds the contacts and the movable contact arm of the circuit breaker. When the circuit is live, an electrical arc may be drawn between the electrical contacts during separation. The electrical current interacts electromagnetically with the slot motor to induce a magnetic field in the magnetic material of the slot motor, which, in turns, interacts with the separating contacts and the movable contact arm to accelerate the contact opening process. Examples of slot motors are disclosed in U.S. Patent Nos. 4,375,021; 4,546,336; 4,546,337; 4,549,153; 4,970,482; 5,694,098, and 6,281,459.

Slot motors generally have two assemblies, an upper assembly and a lower assembly. Both upper and lower assemblies include a corresponding housing and a plurality of plates composed of the magnetically permeable material. The lower assembly is disposed below the fixed contact. As shown in Figure 1, the upper
5 assembly is an inverted U-shaped assembly having a housing assembly 1 and a plurality of plates 2, forming a bight portion 3 and two legs 4,5. The upper slot motor assembly is structured to be disposed over the movable contact (not shown) wherein the tips of the upper assembly legs 4,5 contact the lower slot motor assembly (not shown). The upper assembly legs 4,5 have an extended length to accommodate the
10 path of travel of the movable contact arm (not shown). That is, the movable contact (not shown) is disposed between the upper assembly legs 4,5 and as the movable contact moves between the first, open position and the second, closed position, the movable contact moves from a position adjacent to the upper assembly bight portion 3 to a position adjacent the tips of the legs 4,5. Accordingly, the legs 4,5 have a
15 sufficient length to accommodate the path of travel of the movable contact arm.

There is room for improvement in electrical switching apparatus, such as circuit breakers, employing a slot motor.

SUMMARY OF THE INVENTION

These needs and others are met by the present invention which
20 employs the rigid legs of a slot motor to reinforce the exterior walls of a circuit breaker housing. In addition to increasing the strength of the circuit breaker housing, this structure reduces parts, since it eliminates a corresponding slot motor housing assembly and, instead, employs the circuit breaker housing.

As one aspect of the invention, an upper slot motor assembly for a
25 circuit breaker slot motor assembly comprises: a circuit breaker housing including a circuit breaker base having a first opening and a second opening; and a rigid magnetic member having a bight portion, a first leg, and a second leg, the first leg of the rigid magnetic member engaging the circuit breaker base of the circuit breaker housing at the first opening, the second leg of the rigid magnetic member engaging the circuit
30 breaker base of the circuit breaker housing at the second opening.

The rigid magnetic member may comprise a plurality of laminated U-shaped plates resting in a U-shaped holder. Each of the laminated U-shaped plates

may include a bight portion, and a pair of legs. The U-shaped holder may include a bight portion engaging the bight portion of each of the laminated U-shaped plates and a pair of legs engaging the pair of legs of each of the laminated U-shaped plates.

5 The circuit breaker base of the circuit breaker housing may include a plurality of first interior walls and a first exterior wall, which define the first opening of the circuit breaker base, and a plurality of second interior walls and a second exterior wall, which define the second opening of the circuit breaker base. The first and second legs of the rigid magnetic member may engage the first and second interior walls, in order to reinforce the first and second exterior walls, respectively, of
10 the circuit breaker base.

The first and second exterior walls may have a first thickness, and the first and second legs of the rigid magnetic member may have a second thickness, which is greater than the first thickness. The first and second interior walls may have a third thickness, which is less than the first thickness.

15 As another aspect of the invention, a circuit breaker comprises: a housing including a first opening and a second opening; at least one pair of separable contacts including a stationary contact and a movable contact disposed in the housing; an operating mechanism disposed in the housing and coupled to the separable contacts, the operating mechanism being structured to move the separable contacts
20 between an open position and a closed position; a trip mechanism disposed in the housing and coupled to the operating mechanism, the trip mechanism being structured to actuate the operating mechanism to open the separable contacts; and a slot motor assembly disposed about the separable contacts, the slot motor assembly having an upper slot motor assembly and a lower slot motor assembly, the lower slot motor
25 assembly being disposed below the stationary contact, the upper slot motor assembly being disposed above the movable contact, the upper slot motor assembly comprising a rigid magnetic member having a bight portion, a first leg, and a second leg, the first leg of the rigid magnetic member engaging the housing within the first opening, the second leg of the rigid magnetic member engaging the housing within the second
30 opening.

The rigid magnetic member may comprise a plurality of laminated U-shaped steel plates resting in a U-shaped holder.

The housing may further include a plurality of first interior walls and a first exterior wall, which define the first opening, and a plurality of second interior walls and a second exterior wall, which define the second opening. The first and second legs of the rigid magnetic member may engage the first and second interior walls, in order to reinforce the first and second exterior walls, respectively.

The first and second interior walls of the housing in combination with the first and second legs may limit motion of the first and second exterior walls, respectively, of the housing during interruption of a power circuit when the separable contacts move from the closed position to the open position in response to the trip mechanism. The first and second interior walls of the housing in combination with the first and second legs may enable the first and second exterior walls, respectively, of the housing to withstand pressure within the housing during interruption of the power circuit.

The first and second legs may provide a continuous bridge between the first and second interior walls of the housing and the first and second exterior walls, respectively, of the housing.

The rigid magnetic member may be installed in the circuit breaker after assembly of the trip mechanism and the operating mechanism in the housing.

As another aspect of the invention, an electrical switching apparatus comprises: a housing including a first opening and a second opening; separable contacts including a first contact and a second contact disposed in the housing; an operating mechanism disposed in the housing and coupled to the separable contacts, the operating mechanism being structured to move the separable contacts between an open position and a closed position; a trip mechanism disposed in the housing and cooperating with the operating mechanism to trip open the separable contacts; and a slot motor assembly disposed about the separable contacts, the slot motor assembly having a first slot motor portion and a second slot motor portion, the first slot motor portion being disposed proximate the first contact, the second slot motor portion being disposed proximate the second contact, the first slot motor portion comprising a rigid magnetic member having a bight portion, a first leg, and a second leg, the first leg of the rigid magnetic member engaging the housing at the first opening, the second leg of the rigid magnetic member engaging the housing at the second opening.

The first and second openings may have four sides. The housing may further include three first interior walls and a first exterior wall, which define the four sides of the first opening, and three second interior walls and a second exterior wall, which define the four sides of the second opening. The first and second legs of the
5 rigid magnetic member may include four sides, which engage the four sides of the first and second openings, in order to reinforce the first and second exterior walls, respectively.

BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the invention can be gained from the following
10 description of the preferred embodiments when read in conjunction with the accompanying drawings in which:

Figure 1 is an isometric view of an upper slot motor assembly.

Figure 2 is a simplified isometric view of a circuit breaker, with the cover removed for convenience of illustration, including a circuit breaker housing
15 having a base with openings holding a rigid magnetic member in accordance with an embodiment of the present invention.

Figure 3 is an isometric view of the slot motor laminated plates of Figure 2.

Figure 4 is an isometric view of the U-shaped holder of Figure 2.

20 Figure 5 is an isometric view of the circuit breaker base of Figure 2.

Figure 6 is a partially exploded, simplified isometric view of part of a three-phase circuit breaker housing including a base and a cover, with three cover portions exploded for convenience of illustration, in which both the base and the cover have openings for holding rigid magnetic members in accordance with another
25 embodiment of the invention.

Figure 7 is an isometric view of a three-phase circuit breaker housing, with the cover removed for convenience of illustration, including a base having openings for holding rigid magnetic members in accordance with another embodiment of the invention.

30 Figure 8 is a longitudinal section of a side elevational view, partially broken away and partially in phantom, of an internal portion of the circuit breaker of Figure 7.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Figure 2, a single pole circuit breaker 8 includes a molded housing 10 having a molded base 12 with first and second openings 14,16 molded therein for holding an upper slot motor assembly 18. Although a single pole circuit breaker 8 is shown, the invention is applicable to a wide range of electrical switching apparatus having a wide range of phase or pole counts.

Although a simplified view of the circuit breaker 8 is shown in Figure 2, it will be appreciated that this circuit breaker 8 includes a cover (not shown), separable contacts 21A, an operating mechanism 22A, an arc chamber 23A, a trip mechanism 24A, and a slot motor assembly 26A disposed about such separable contacts. For example, the three-pole circuit breaker 19 of Figure 8 includes a cover 20, separable contacts 21, an operating mechanism 22 coupled to the separable contacts 21 and structured to move such contacts between an open position (not shown) and a closed position, a trip mechanism 24 structured to actuate the operating mechanism 22 to trip open the separable contacts 21, a slot motor assembly 26 disposed about the separable contacts 21, and a base 28. The slot motor assembly 26 includes an upper slot motor assembly 156A and a lower slot motor assembly 156B. As will be explained, below, this circuit breaker 19, similar to the circuit breaker 8 of Figure 2, incorporates the slot motor assembly 26 within the circuit breaker base 28.

Referring to Figures 2-5, the upper slot motor assembly 18 is a rigid magnetic member 31 having a general U-shape (*e.g.*, made from a plurality of laminations stacked together; made from a solid machined or cast piece), with a bight portion 32, a first leg 34, a second leg 36, and a gap 38 between the first and second legs 34,36. The first leg 34 engages the base 12 at the first opening 14 and the second leg 36 engages the base 12 at the second opening 16. In this example, the member 31 includes a plurality of laminated U-shaped plates 40 (*e.g.*, steel; a suitable iron based alloy; a suitable ferrous material) resting in a U-shaped holder 42 (*e.g.*, made of a suitable thermoset plastic material). The U-shaped holder 42 engages the base 12 proximate the first and second openings 14,16. The magnetic member 31 is preferably installed in the circuit breaker housing 10 after assembly of the trip mechanism 24A and the operating mechanism 22A in the housing 10.

As shown in Figure 3, each of the laminated U-shaped plates 40 includes a bight portion 44, a pair of legs 46,48, and a gap 50 between the pair of legs 46,48. The U-shaped holder 42 of Figure 4 includes a bight portion 52 engaging the bight portion 44 of each of the laminated U-shaped plates 40 and a pair of legs 54,56 engaging the pair of legs 46,48, respectively, of each of the laminated U-shaped plates 40.

Continuing to refer to Figures 3 and 4, the laminated U-shaped plates 40 include a first laminated U-shaped plate 40A, a plurality of second or central laminated U-shaped plates 40B and a third laminated U-shaped plate 40C. The U-shaped holder 42 further includes a first U-shaped edge 58 engaging the first laminated U-shaped plate 40A and a second U-shaped edge 60 engaging the third laminated U-shaped plate 40C. The second laminated U-shaped plates 40B are laminated between the first and third laminated U-shaped plates 40A,40C. Preferably, a sufficient count of the plates 40A,40B,40C is employed such that the combination of these plates is compressively held between the U-shaped edges 58,60. Preferably, a suitable minimal clearance is provided between the legs 54,56 and the respective openings 14,16, in order to minimize flexing of the housing base 12. The laminated U-shaped steel plates 40A,40B,40C and the U-shaped holder 42 form the magnetic member 31 of Figure 2.

The housing base 12 of Figure 5 includes a plurality of first interior walls 62',64,66 and a first exterior wall 68, which define the first opening 14, and a plurality of second interior walls 70,72,74 and a second exterior wall 76, which define the second opening 16. The first leg 34 and the second leg 36 of the magnetic member 31 of Figure 2 engage the first interior walls 62,64,66 and the second interior walls 70,72,74, in order to reinforce and add rigidity to the first exterior wall 68 and the second exterior wall 76, respectively.

The first and second exterior walls 68,76 have a first thickness 78. The first and second legs 34,36 of the magnetic member 31 (and the openings 14,16) have a second thickness 80 (shown in Figures 3 and 5), which is greater than the first thickness 78. The first interior walls 62,64,66 and the second interior walls 70,72,74 in combination with the first leg 34 and the second leg 36 limit motion of the first exterior wall 68 and the second exterior wall 76, respectively, during interruption of a

power circuit (not shown) (*e.g.*, when the separable contacts 21A of Figure 2 move from the closed position to the open position in response to the trip mechanism 24A). This combination also enables the exterior walls 68,76 to withstand the build-up of relatively extreme pressure within the housing 10 of Figure 2 during interruption of the corresponding power circuit (not shown). Preferably, the first and second legs 34,36 provide a continuous bridge between the first and second interior walls 62,64,66 and 70,72,74 and the first and second exterior walls 68 and 76, respectively. A third thickness 82 of the interior walls, such as 64,72, is smaller than the first exterior wall thickness 78. The combination of the interior walls 62,64,66 and 70,72,74 with the steel laminations of the legs 34 and 36 of Figure 2, limits the motion of the base exterior walls 68 and 76, respectively, during relatively extreme pressure “build-up” encountered during interruption, which prevents the fracturing of such exterior walls.

Example 1

Non-limiting examples of the thicknesses 78, 80 and 82 are 0.200”, 0.250” and 0.060” (minimum), respectively.

Example 2

Alternatively, the second thickness 80 of the magnetic member legs may be less than the first thickness 78 of the exterior walls.

Each of the first and second openings 14,16 of Figure 5 has four sides 84,86,88,90. For example, the three first interior walls 62,64,66 and the interior surface of the first exterior wall 68 define the four sides of the first opening 14. Similarly, the three second interior walls 70,72,74 and the interior surface of the second exterior wall 76 define the four sides of the second opening 16. The first and second legs 34,36 of the magnetic member 31 of Figure 2 include four sides 92,94,96,98 (generally shown in Figure 2, with side 94 shown in Figure 3), which engage the four sides 84,86,88,90 of the first and second openings 14,16 (as shown with the opening 14 of Figure 5), in order to reinforce and add rigidity to the first and second exterior walls 68,76, respectively.

Referring to Figure 6, a three-phase circuit breaker molded housing 100 includes a molded base 102 and a molded cover 104 having three cover portions

106,108,110 (shown exploded for convenience of illustration). Here, both the base 102 and the cover 104 have six openings 111,112,113,114,115,116 (as shown only with the cover 104) molded therein for holding three rigid magnetic members 118A,118B,118C (*e.g.*, three of the rigid magnetic members 31 of Figure 2). For example, the legs 34,36 of the rigid magnetic member 118A engage the molded cover 104 at the openings 111,112, respectively. The legs 34,36 of the rigid magnetic member 118B engage the molded cover 104 at the openings 113,114, and the legs 34,36 of the rigid magnetic member 118C engage the molded cover 104 at the openings 115,116, respectively.

Again, the rigid magnetic members 118A,118B,118C are installed after assembly of circuit breaker assembly 120 (as shown in block form in hidden line drawing) (including, *e.g.*, separable contacts, operating mechanism, trip mechanism, lower slot motor assembly, arc chamber) is complete. This adds rigidity to the entire circuit breaker molded housing 100 (*e.g.*, the base 102 and the cover 104) and enables the exterior case walls 122,124 to withstand relatively greater pressure forces. Another advantage of this embodiment is that it is possible to readily change from a standard performance circuit breaker (*e.g.*, without a slot motor) to a relatively high performance circuit breaker (*e.g.*, with a slot motor), thereby, eliminating different manufacturing styles.

Figure 7 shows another three-phase circuit breaker molded housing 126, with the molded cover (not shown) removed for convenience of illustration. This housing 126 includes the molded base 28, which is similar to the molded base 102 of Figure 6, having six openings 131,132,133,134,135,136 for holding three rigid magnetic members 138A,138B,138C (*e.g.*, three of the rigid magnetic members 31 of Figure 2). For example, the legs 34,36 of the rigid magnetic member 138A engage the molded base 28 at the openings 131,132, respectively. The legs 34,36 of the rigid magnetic member 138B engage the molded base 28 at the openings 133,134, and the legs 34,36 of the rigid magnetic member 138C engage the molded base 28 at the openings 135,136, respectively. Although the members 138A,138C add rigidity to the exterior walls 140,142, the members 138A,138B,138C also add rigidity to the interior walls 144,146.

Referring now to Figure 8, the circuit breaker 19 includes a load terminal 150 and a line terminal 152. There is shown a plasma arc acceleration chamber 154 comprising the slot motor assembly 26 and an arc extinguisher assembly 158. Also shown is a contact assembly 160, the operating mechanism 22, and the trip mechanism 24. Although not viewable in Figure 8, each phase of the three-phase circuit breaker 19 has its own load terminal 150, line terminal 152, plasma arc acceleration chamber 154, slot motor assembly 26, arc extinguisher assembly 158, and contact assembly 160.

Each slot motor assembly 26 includes a separate first or upper slot motor portion or assembly 156A, which is disposed proximate or above the first or movable contact 180, and a second or lower slot motor portion or assembly 156B, which is disposed proximate or below the second or fixed contact 184. The upper slot motor assembly 156A includes a plurality of plates 168 and is structurally and functionally similar to the magnetic member 31 of Figure 2. Similar to that magnetic member, the first and second legs 186,187 (only leg 186 is shown in Figure 8) of the upper slot motor assembly 156A engage the base 28 at or within two corresponding openings 131,132 (only opening 131 with interior walls 62' and 66' is shown in Figure 8).

The lower slot motor assembly 156B includes a lower slot motor assembly housing 170 within which are stacked side-by-side lower slot motor assembly plates 172 composed of magnetic material. The lower slot motor assembly 156B is structurally and functionally similar to that described in U.S. Patent Nos. 5,910,760 and 6,452,470, which are incorporated herein by reference.

The plates 168 and 172 form an essentially closed electromagnetic path in the vicinity of movable contact 180 and stationary contact 184. At the beginning of a contact opening operation, electrical current continues to flow in a movable contact arm 178 and through an electrical arc created between contacts 180 and 184. This current induces a magnetic field into the closed magnetic loop provided by upper plates 168 and lower plates 172 of upper slot motor assembly 156A and lower slot motor assembly 156B, respectively. This magnetic field electromagnetically interacts with the current in such a manner as to accelerate the movement of the movable contact arm 178 in the opening direction whereby contacts 180 and 184 are more

rapidly separated. The higher the magnitude of the electrical current flowing in the arc, the stronger the magnetic interaction and the more quickly contacts 180 and 184 separate.

For very high current (*e.g.*, an overcurrent condition), the above
5 process provides a blow-open operation in which the movable contact arm 178 forcefully rotates upwardly about pivot pin 190 and separates contacts 180 and 184, this rotation being independent of crossbar assembly 192. This blow-open operation is shown and described in U.S. Patent No. 3,815,059, which is incorporated herein by reference, and provides a faster separation of contacts 180 and 184 than can normally
10 occur as the result of a tripping operation generated by the trip mechanism 24.

Although generally rectangular openings 14,16 and legs 34,36 are disclosed, a wide range of cross-sectional shapes (*e.g.*, three sided; rounded; circular; square; five or more sided) may be employed.

Although the rigid member 31 has a general U-shape, a wide range of
15 shapes and sizes may be employed. For example, the U-shape may have square or rounded corners. Although the legs 34,36 are preferably parallel, those may be angled outward or inward to the extent that the openings 14,16 are suitably modified to receive the legs.

While specific embodiments of the invention have been described in
20 detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of the invention which is to be given the full breadth of the claims appended and any and all equivalents thereof.